P 1.38

Quantifying Uncertainties in Fire Size and Temperature Measured by GOES-R ABI

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Background

GOES-R risk reduction requires advance creation of synthetic satellite imagery and using them to create and evaluate new products before satellite launch.
The synthetic satellite imagery should realistically represent events for the fields to be useful for pre-launch product development and assessment.
Creation of synthetic imagery requires computation of radiance for high resolution fields.
Point spread function that are representative of GOES-R ABI bands are then applied on the high resolution radiance data to create GOES-R footprints.
Fires because of their nature are often smaller in size than a satellite pixel (Nominal GOES-R ABI pixel of 2km X 2km in this instance).
The location of a sub-pixel fire within a GOES-R pixel determines its influence on the GOES-R ABI footprint with central locations having higher influence.
Therefore a fire of the same size and temperature will result in varying GOES-R ABI pixel brightness temperature based on the location of the fire within the pixel.
Our goal is to investigate the uncertainty in fire detection based on fire location with a GOES-R pixel.

General Procedure

Create high resolution point spread function tables (50m X 50 m resolution) for channels used in fire detection (3.9 µm, 10.35 µm and 11.2 µm) from available 1 km resolution point spread function.
Use a synthetic atmospheric profile and compute radiances for GOES-R ABI fire detection bands.
Add fire to surface of the profile and compute radiances for the 3 bands. Increase the fire temperature to create a database.
Use the previously computed radiances and compute radiances for a GOES-R ABI pixel that contain sub-pixel fires. Note that the ABI pixel size varies and different pixel sizes have to be considered to exhaustively cover North America.
Create brightness temperature distributions based on probability of sub-pixel fire location within the GOES-R pixel.

Modeling specifics

(a) Point spread function
Extract cumulative distribution function from 1km data for the central 3kmX3km area.
Use computed cdf as constraint in a bivariate normal distribution to create a high resolution normalized pdf.
(b) Radiative transfer computation
Gaseous absorption is computed using OPTRAN (Mcmillin et al. 1995).
Condensate optical properties is computed using Anomalous Diffraction theory (Greenwald et al. 2002).
Radiance computations are made using a delta-eddington scheme (infrared) and a plane parallel version of the Spherical Harmonics Discrete Ordinate Method (SHDOMPP) (Evans 1998).
(c) Brightness temperature distribution based on fire location.
Ambient surface temperature used is 288 K. Fire temperatures are increased by 50 K with maximum fire temperature being around 1300 K.
Fire sizes range from 50m X 50m to 500m X 500 m.

Results

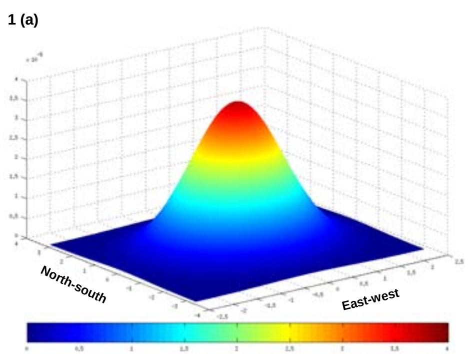


Figure 1(a): This figure represents the normalized probability density function for a GOES-R ABI pixel at 3.9 µm over Kansas representing the point spread function (psf). The nominal pixel size is approximately 2.4 km (East West) X 3.2 km (North-South) while the total area for the psf is 4.8 km X 6.4 km and covers over 99.5% of a bivariate normal pdf. The core area is seen to contain 73% of the total pixel information.

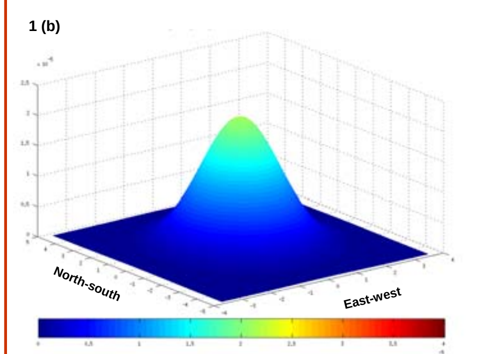
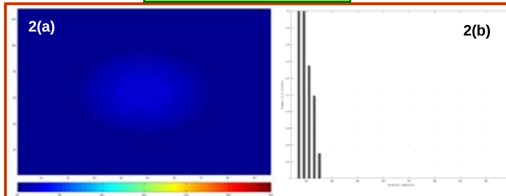
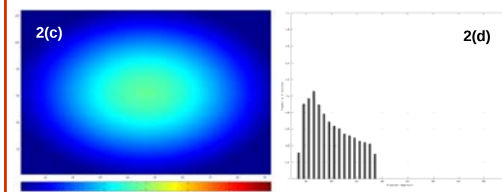


Figure 1(b): This figure represents the normalized probability density function for a GOES-R ABI pixel at 10.35 µm over Kansas representing the point spread function (psf). The nominal pixel size is approximately 2.4 km (East West) X 3.2 km (North-South) while the total area for the psf is 7.2 km X 9.6 km and covers over 99.5% of a bivariate normal pdf. The core area is seen to contain 53% of the total information.

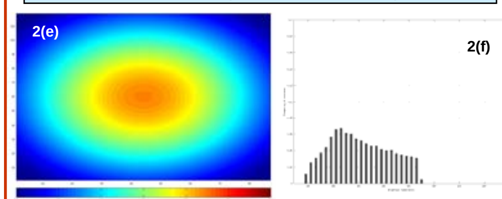
3.9 µm GOES-R ABI band



Fire size 50m X 50 m; fire temperature 988 K; surface temperature 288 K

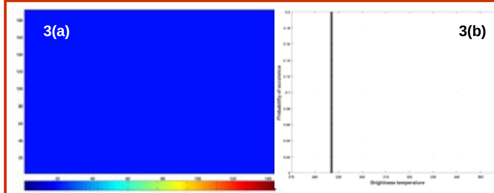


Fire size 250m X 250 m; fire temperature 988 K; surface temperature 288 K

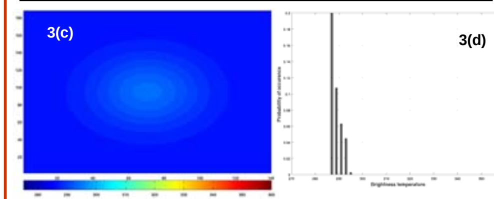


Fire size 500m X 500 m; fire temperature 988 K; surface temperature 288 K

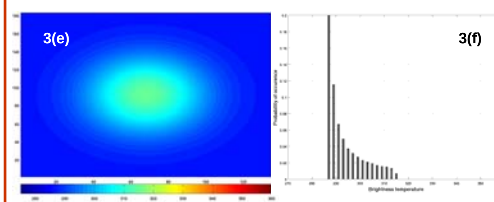
10.35 µm GOES-R ABI band



Fire size 50m X 50 m; fire temperature 988 K; surface temperature 288 K



Fire size 250m X 250 m; fire temperature 988 K; surface temperature 288 K



Fire size 500m X 500 m; fire temperature 988 K; surface temperature 288 K

Figures 2 & 3: The two sets of figures above show how brightness temperature of a GOES-R ABI pixel will vary based on location and size of a sub-pixel fire. Note the much higher sensitivity of the 3.9 µm channel.

Wavelength (µm)	Fire Temperature (K)	Fire Size (m X m)	Mean (K)	Median (K)	Standard Deviation (K)	Minimum (K)	Maximum (K)
3.9	588	50 X 50	287	286	1	286	291
		250 X 250	302	296	15	286	340
		500 X 500	325	319	28	286	384
	988	50 X 50	295	291	10	286	324
		250 X 250	349	341	42	287	438
		500 X 500	404	398	59	293	522
10.35	588	50 X 50	286	286	0	286	286
		250 X 250	286	286	1	286	289
		500 X 500	288	287	2	286	296
	988	50 X 50	286	286	0	286	286
		250 X 250	287	286	2	286	294
		500 X 500	291	288	7	286	315

Table 1: This table shows representative statistics of GOES-R ABI pixel brightness temperature over Kansas for fires of different sub-pixel sizes and temperatures. The core GOES-R pixel area is taken to be 2.4 km (East-West) and 3.2 km (North South). The point spread function is assumed to have significant contribution over a 4.8 km X 6.4 km area. 2 wavelengths, 2 fire temperatures and 3 fire sizes are shown. The background surface temperature is 288 K.

Conclusions and future work

Point spread functions for the GOES-R ABI channels were created at high resolution using a bivariate normal distribution.

The impact of point spread function on sub-pixel fires has been shown to be significant especially for the 3.9 µm GOES-R ABI band.

Because of spatial variations in the size of GOES-R pixels for all bands it may be possible to detect smaller and cooler fires at sub-satellite point.

We expect to quantify the sensitivity of the 3 channels used in fire detection to fires of various sizes and temperatures. This is will ultimately provide information for use in fire detection.

References:

Evans, K. F., 1998: The Spherical Harmonics Discrete Ordinate Method for Three-Dimensional Atmospheric Radiative Transfer, *J. Atmos. Sci.*, 55, 429-446.

Greenwald, T. J., R. Hertenstein, and T. Vukicevic, 2002: An all-weather observational operator for radiance data assimilation with mesoscale forecast models. *Mon. Wea. Rev.*, 130, 1882-1897.

McMillin, L. M., L. J. Crone, M. D. Goldberg, and T. J. Kleespies, 1995: Atmospheric transmittance of an absorbing gas, 4. OPTRAN: A computationally fast and accurate transmittance model for absorbing gases with fixed and variable mixing ratios at variable viewing angles, *Appl. Opt.*, 34, 6269-6274.